Real Paths of 107 *Meteors observed during the Ten Years ending*
1896 *November.*   By W. F. Denning.

The following are the heights, radiants, &c. of such fireballs
and shooting stars as have been observed at two or more stations
in England during recent years, and submitted to comparison
and calculation by the writer.   Some of the results have been
published before in a detached form in the Journals of the Liver-
pool Astronomical Society and British Astronomical Association,
and in *The Observatory* or *Nature*.   They are now brought
together in a complete form, and arranged according to the day
of the year.   It is thought this plan will facilitate reference and
prevent troublesome searches amongst various publications on the
part of those making inquiries into the subject.   Many of the ob-
servations were made in connection with the meteoric sections of
the two societies above named.   The principal observers were
Mr. H. Corder, Bridgwater ; Mr. D. Booth, Leeds ; Professor A. S.
Herschel, Slough ; and the writer, Bristol.   Several other
observers contributed useful observations, and the abbreviations
are :—

T. W. B.	T. W. Backhouse, Sunderland.
E. R. B.	E. R. Blakeley, Dewsbury.
D. B.	D. Booth, Leeds.
H. C.	H. Corder, Bridgwater.
G. T. D.	G. T. Davis, Reading.
W. F. D.	W. F. Denning, Bristol.
J. E.	J. Evershed, Kenley, Surrey.
A. S. H.	A. S. Herschel, Slough.
S. A. S.	S. A. Saunder, Wokingham, Berks.

In the column headed " Velocity " " v." means very, " sw."
swift, " m." moderate or medium speed.

The greatest height of any well-observed meteor in the list
was that of a small Perseid (No. 65) seen before sunrise on 1893
August 15, which at its first appearance was 126 miles above the
Earth's surface.
The height of ordinary meteors is seldom above 100 miles.
There are, however, some notable exceptions.   A meteor of the
first magnitude was seen at the same time on 1890 December 9
by Mr. Booth at Leeds and by myself at Bristol, and the obser-
vations, which appear quite consistent, indicate a height of 208
miles at first appearance and 165 at disappearance, but the figures
are so exceptional when compared with others that I have, in
order to be on the safe side, rejected the observation.

The average values derived from all the results summarised in the table are :—

Height at first appearance 73·6 miles (106 meteors)
    ,,   disappearance 45·3 ,,   (107   ,,   )
Length of Path   62·1   ,,   (105   ,,   )
Velocity   26·9   ,,   (58   ,,   )

It must be remembered that these values are from a promiscuous collection of fireballs and shooting stars. Fireballs usually penetrate much lower into the atmosphere than small meteors, and they exhibit a longer flight and slower motion.

Catalogues of the real paths of meteors are not without their uses, as they supply data for after comparison. When one of these objects is seen, and its course determined from several independent observations, it is interesting to see if it accords with any meteor or meteor-shower noticed in preceding years. Thus on 1896 September 10, 9^h 3^m, a brilliant meteor was recorded by many persons in England, and a comparison of the paths showed that it was directed from a radiant at 72°+42° in *Auriga* (No. 72). Now referring to Professor G. von Niessl's Catalogue we find two fireballs as follow :—

No. 78, 1866 Sept. 6   = ☽.   Radiant 79 + 44.
No. 79, 1869 Sept. 8   4 × ♃.   Radiant 70 + 45.

The inference is therefore that the three objects belonged to one and the same stream. Extending the comparison to meteor showers we shall find the following radiants exhibit a good accordance in date and position :—

Tupman, No. 66, 1870, Aug. 29 . . . 75 + 45
Denning, No. 520, 1885, Sept. 12–15 . 73 + 43
  ,,   No. 549, 1879, Sept. 15–16 . 72 + 41

The mean positions of the radiants of the three fireballs and of the three meteor showers are as follow :—

Fireballs, Sept. 6–10 . . . 73·7 + 43·7
Meteor showers, Aug. 29–Sept. 16. 73·3 + 43·0

The agreement could scarcely be more satisfactory.

Such materials are also valuable for the purpose of investigating long-continued radiants, or radiants which, like that of the *Perseids*, shift their position amongst the stars. Thus Nos. 8 and 13 showed radiants nearly identical in *Cepheus*, while Nos.

17, 27, 35, &c., are near together in *Libra*. Among such resemblances some may be purely accidental, but the agreements in certain cases are so striking, and particularly those found in the radiants of meteor showers, that they deserve careful attention.

The apparent radiants of fireballs are often not so accurate as could be wished, owing to the nature of the observations which are more or less imperfect and incorrect. Happily, a decided improvement has been shown in recent years both in the number and quality of such records. Though a vast number of brilliant fireballs have been allowed to escape suitable investigation in the past, it is hoped the time will soon arrive when most of these bodies, which appear over Europe and America, will be sufficiently well observed to enable their real paths to be calculated with precision.

Bristol : 1896 *December* 6.

107 *Real paths of Fireballs and Shooting Stars observed in England from 1886 to 1896.* By W. F. Denning.

No.	Year.	Month and Day.	G.M.T.	Mag.	Height at Appearance.	Height at Disappearance.	Length of Obs. Path.	Velocity.	Radiant Point. α δ	Observers.	Notes.
			h m		miles	miles	miles		° °		
1	1894 Jan.	1	10 9	2 – 1	50	34	20	v. sw.	107 + 25	H. C. and W. F. D.	Left a streak.
2		1	10 44	2	80	77	52	52	185 + 15	A. S. H. and W. F. D.	Radiant just risen.
3	1895	1	6 43	3 – 2½	58	47	30	13	233 + 56	H. C. and W. F. D.	Quadrantid.
4		1	7 23½	1½ – 1	65	50	41	10	62 – 12	,,	Left a train of yellow sparks.
5	1894	2	9 40	3 – 2	65	56	53	21	240 + 48	A. S. H. and H. C.	Nucleus orange yellow.
6	1888	2	10 58	♃	98	60	109	44	250 + 57	D. B. and W. F. D.	Radiant η – θ Draconis.
7	1887	19	11 19	2 – 1	56	28	33	22	174 + 70	T. W. B. and W. H. S. Monck	Radiant at λ Draconis.
8	1894	25	10 1	☽	89	16	160	18	331 + 55	W. F. D. and others	Detonated, 45 observations.
9	Feb.	8	0 28	☽	80	20	...	sw.	Hercules	A. A. Rambaut and others.	In bright sunshine.
10		21	7 18	♃	...	30	...	sw.	141 + 52	W. F. D. and others	Not well observed.
11	1887	26	11 24	4	56	50	21	21	302 + 53	J. E. and W. F. D.	Radiant near ψ Cygni.
12	1896 Mar.	1	8 32	3 – 1½	55	55	405	20	18 + 5	T. W. B. and J. E. Clark	A very long flight. Radiant near horizon.
13	1895	10	14 27	♃ – ♀	50	23	58	19	330 + 59	H. C., A. Mee, and others	} Seen during a total eclipse of the Moon, 6 obs. of No. 13.
14		10	15 24	♃	80	40	41	sw.	240 + 63	G. T. D. and others	
15	1896	16	10 13	♀	33	29	63	m.	205 – 18	R. B. Saul and others	Compare No. 17.
16	1887	27	8 49	1	59	55	23	10	11 + 35	T. W. B. and W. F. D.	Left a bright train.

No.	Year	Month and Day	G.M.T.	Mag.	Height at Appearance	Height at Disappearance	Length of Obs. Path	Velocity	Radiant Point. α δ	Observers	Notes
			h m		miles	miles	m l s		° °		
17	1896 Apr.	8	8 20	1 − ♀	65	38	161	20	204 − 9	H. C., J. E., S. A. S., and others	Compare No. 15.
18		12	8 6	☽	118	34	177	19	50 + 42	F. W. Dyson and others	Radiant perhaps at 50 + 31.
19	1895	14	11 44	1	87	71	107	49	316 + 31	A. S. H. and W. F. D.	Compare No. 24.
20	1893	15	9 52	☽	99	40	158	32	15 + 59	Many Observers	Inexact.
21	1895	19	10 59	1 − ♀	91	43	97	33	269 + 30	H. C., E. R. B., W. F. D., and others	A fine Lyrid.
22		19	11 46	1	77	70	40	50	300 + 20	H. C. and W. F. D.	Left an orange streak.
23	1893	20	11 56	3 − 1½	67	48	28	24	198 + 5	A. S. H. and W. F. D.	Compare No. 35.
24		20	12 39½	2 − 1	75	68	35	49	314 + 27	,,	Compare No. 19.
25		20	12 44	4 − 3	77	68	23	sw.	292 + 17	H. C. and W. F. D.	Left a streak.
26	1889	20	10 16	2 − 1	51	46	22	29	301 + 36	A. S. H. and T. W. B.	Radiant γ Cygni.
27		21	10 16	2 − 1	72	54	42	28	218 − 5	A. S. H. and W. F. D.	Radiant μ Libræ.
28	1893	21	13 38	5 − 3	62	45	37	slow	226 + 11	H. C. and W. F. D.	Radiant near β Libræ.
29		21	15 15½	3 − 2	80	65	33	v. sw.	299 ± 0	,,	Left a streak.
30	1894	22	7 36	☽	80	17	120	30	α − β Persei	J. E. and others	Inexact. In twilight, 20 obs.
31	1887 May	8	8 22	☽	70	14	110	18	191 − 5	Many observers	Left a bright train.
32		9	10 27	3	73	50	37	slow	234 + 9	D. B. and W. F. D.	Radiant close to α Serpentis.
33	1893	9	11 21	♃	76	40	54	13	202 + 6	S. A. S. and W. F. D.	Compare No. 23.
34	1889	22	19 8	1 − ♃	59	58	292	14	63 + 35	G. T. D. and W. F. D.	Radiant on horizon.

No.	Year.	Month and Day.	G.M.T.	Mag.	Height at Appearance.	Height at Disappearance.	Length of Obs. Path.	Velocity.	Radiant Point. α δ	Observers.	Notes.
			h m		miles	miles	miles		° °		
35	1889	May 29	10 44	☽	59	22	75	8	215 −7	D. B. and I. W. Ward	Compare Nos. 27 and 37.
36	1895	June 10	9 59	☽	58	44	89	18	259 −23	D. B. and others	Broke into three fragments.
37		July 7	10 49	☽	53	30	79	9	217 −6	F. W. Dyson and others	Compare Nos. 27 and 35.
38	1891	13	12 54	> 1	82	50	154	...	58 +33	D. B. and J. Sherwen	Left a bright streak.
39	1887	19	10 48	3 − 2	59	55	18	slow	104 +52	J. E. and W. F. D.	Left a streak.
40		21	11 24½	4	65	51	18	sw.	291 +47	„	Radiant near δ Cygni.
41		22	13 12½	1 − 4	80	40	41	27	307 +44	D. B. and W. F. D.	Radiant near α Cygni.
42	1886	Aug. 4	10 40	☽	90	11	168	21	161 +59	W. F. D. and others	A brilliant Ursid fireball.
43	1888	5	10 18½	3 − 1	69	50	41	slow	50 +55	G. T. D. and W. F. D.	Perseid. Left a streak.
44		5	10 29½	4 − 3	69	48	38	sw.	39 +57	„	„ „
45		5	10 41½	4 − 3	68	48	41	sw.	43 +51	„	„ „
46	1896	6	10 6	1	75	49	47	32	42 +61	H. C. and W. F. D.	Perseid.
47	1895	7	10 12	3 − 2	43	28	42	sw.	45 +47	„	Radiant near α Persei.
48		7	11 4	1 − 4	74	45	33	m.	333 +36	A. S. H., H. C., and W. F. D.	A bright Lacertid.
49		7	11 28	2	105	63	64	sw.	38 +57	H. C. and W. F. D.	Perseid. Left a streak.
50	1888	7	10 6	5 − 3	70	59	28	sw.	66 +56	G. T. D. and W. F. D.	Camelid. ? Perseid.
51		8	10 10	4 − 3	65	52	38	v. sw.	318 −13	„	A small Aquarid.
52		8	10 21	3	43	28	26	v. sw.	40 +60	„	Perseid. Left a streak.

No.	Year	Month and Day	G.M.T.	Mag.	Height at Appearance. miles	Height at Disappearance. miles	Length of Obs. Path. miles	Velocity.	Radiant Point. α δ ° °	Observers.	Notes.
			h m								
53	1888	Aug. 8	10 27½	4	68	48	36	sw.	42+57	G. T. D. and W. F. D.	Perseid. Left a streak.
54		8	11 16½	1	71	61	22	sw.	60+48	T. W. B. and D. B.	Radiant near μ Persei.
55	1887	10	10 47	2	111	43	120	sw.	44+54	T. W. B. and W. F. D.	Perseid. Left a streak.
56	1893	10	11 0	1	38	23	35	7	304−13	H. C. and W. F. D.	Motion very slow.
57		10	11 55½	1−2l	107	60	69	sw.	43+59	,,	Perseid. Left a streak.
58	1894	10	11 35	1−2l	52	16	54	sw.	43+58	T. W. B. and E. R. B.	,,
59	1896	10	10 6⅕	2	64	46	35	sw.	44+58	S. J. Johnson and W. F. D.	,,
60		10	10 6¾	2	65	52	27	sw.	44+58	,,	Inexact.
61	1895	11	10 7	4	78	62	30	43	48+60	A. S. H. and W. F. D.	,,
62		11	10 58½	1	95	61	53	53	36+57	A. S. H. and H. C.	Left a streak.
63		11	11 42½	2l	75	52	34	22	32+52	,,	,,
64	1888	13	11 33⅓	☽	79	47	48	sw.	43+56	D. B. and W. F. D.	A brilliant Perseid.
65	1887	14	13 46½	4−3	126	87	78	v. sw.	53+57	,,	A Perseid at unusual height.
66	1893	14	11 0	1	60	43	15	slow	294+51	H. C. and W. F. D.	Cygnid. Very short path.
67		15	11 57½	2l	58	21	61	20	186+74	,,	Radiant near χ Draconis.
68	1887	21	11 2	♀	80	45	40	13	264+61	D. B. and W. F. D.	,, ,, ξ ,,
69		21	11 25	4	71	51	26	34	35+63	,,	,, ,, ε Cassiopeiæ.
70	1894	26	10 20	☽	90	30	66	sw.	305+79	H. C. and others	Streak lasted 30ᵐ.

No.	Year.	Month and Day.	G.M.T.	Mag.	Height at Appearance.	Height at Disappearance.	Length of Obs. Path.	Velocity.	Radiant Point. α	δ	Observers.	Notes.
			h m		miles	miles	miles		°	°		
71	1888	Aug. 26	8 18	☽	66	41	25	sw.	278	+52	D. B. and W. F. D.	Left a train.
72	1896	Sept. 10	9 3	<☽	82	65	78	31	72	+42	T. E. R. Phillips and many others	Streak lasted $1\frac{1}{2}^m$, 7 obs.
73	1888	10	10 26	☽	71	30	44	15	330	+71	H. C., W. F. D., and others	Radiant near β Cephei, 15 obs.
74	1888	12	10 2½	1	61	38	24	v. sw.	301	+46	G. T. D. and J. E.	,, ,, δ Cygni.
75	1889	25	8 5	1	46	46	100	8½	244	−22	W. H, Robinson and W. F. D.	,, ,, on WSW. horizon.
76	1891	30	10 2½	♃ − ♀	54	24	56	13	14	+7	D. B. and W. F. D.	,, ,, at ε Piscium.
77	1893	Oct. 1	9 40	☽	105	28	93	v. slow	265	+65	H. C. and others	Inexact.
78	1887	13	10 25	2−1	69	50	26	sw.	73	+61	D. B. and W. F. D.	Radiant in Camelopardus.
79		13	11 25	4−2	70	42	37	sw.	127	+83	,,	,, ,,
80		14	12 5½	5−4	64	40	26	m.	355	+36	,,	,, Andromeda.
81		15	14 48½	3−1½	89	61	39	m.	87	+15	,,	Orionid. Left a streak.
82		20	11 45	4	106	90	34	sw.	87	+15	,,	,, at unusual height.
83		20	12 55	1½−1	92	53	70	sw.	87	+13½	,,	,, Left a streak.
84		20	14 15	2−1	74	41	43	slow	20	+22	,,	Radiant near φ Piscium.
85	1893	Nov. 12	6 53	1−♃	66	36	91	18	40	+6	H. J. Townshend and W. F. D.	,, ,, α Ceti.
86	1896	12	11 8	<♀	52	29	35	...	45	+4	G. T. D. and others	Not very certain.
87		12	15 4	>1	84	54	41	41	66	+18	A. S. H. and H.C.	A bright Taurid.
88		12	15 44	1−♀	100	71	33	v.sw.	138	+34	A. S. H. and H. C.	Same radiant as No. 97.
89	1888	13	17 19	>♃	65	37	34	sw.	149	+25	T. W. B. and W. F. D.	A fine Leonid. Streak for 9^m.
90	1895	14	6 20	2	49	29	40	slow	319	−9	H. C., G, T. D., and S, A, S,	A very late Aquarid.

No.	Year	Month and Day	G.M.T.	Mag.	Height at Appearance.	Height at Disappearance.	Length of Obs. Path.	Velocity*.	Radiant Point. α δ	Observers.	Notes.
			h m		miles	miles	miles		° °		
91	1895	Nov. 14	13 54	>1	95	61	85	63	150+22	A.S.H. and G.C. Thompson	A bright Leonid.
92		14	14 1½	2	85	49	70	46	148+20	A.S.H. and G.C. Thompson	A bright Leonid.
93		14	14 29	1-δ	92	55	60	v.sw.	150+23	A.S.H. and H.C.	A bright Leonid.
94		14	17 27	1-2	100	71	33	33	149+24	H.C. and W.F.D.	Leonid.
95*		14	17 45	3	75	50	29	58	150+24	A.S.H., H.C., and W.F.D.	Leonid.
96		14	17 45	3-2	127	89	45	45	150+22	"	" Doubtful.
97		14	18 5	3-2	70	55	16	32	133+32	"	Very short path.
98	1886	17	7 18	♀	96	21	123	17½	34+19	W.F.D. and others.	A bright Arietid.
99	1891	22	6 55	>1	60	42	47	9½	57+15	D.B. and H.C.	Taurid. Compare next.
100	1895	22	6 50	☽	34	17	45	22	58+22	A.S. Williams and others	A Taurid fireball.
101	1886	Dec. 4	9 7	♀	65	28	48	v.sw.	162+58	W.F.D. and others	Left a streak 1½m. See No. 42.
102	1888	8	13 24	1	91	76	72	34	179+10	T.W.B. and D.B.	Left a bright streak.
103	1892	9	7 39	1	91	57	75	30	103+38	H.C. and W.F.D.	Geminid. Left a bright streak.
104	1895	11	14 59	1-2	53	18	63	v. slow	50+30	H.C. and T.H. Foulkes	Radiant W of ξ Persei.
105	1892	12	10 52	>1	60	36	31	20	110+35	A.S.H., H.C., and W.F.D.	Geminid. Left a bright streak.
106	1886	12	11 20	2	85	44	50	38	111+34	H.C. and W.F.D.	Geminid.
107	1886	28	10 28	1	97	39	62	20	77+30	W.F.D. and another	Left a bright train.

* There appear to have been several small Leonids at about 17^h 45^m. No. 95 is, however, an excellent accordance depending upon three good observations. No. 96 is doubtful, and ought perhaps to be rejected.

Catalogue of Real Paths of Large Meteors. By Professor Gustav von Niessl.

(Communicated by W. F. Denning.)

The following real paths of large meteors have been computed by me in recent years.

The descriptions of the objects were partly collected by myself, partly taken from various scientific papers and journals, viz. from Heis's *Wochenschrift für Astronomie, Reports of Vienna Academy*, the *Comptes Rendus* of the French Academy, the *American Journal of Science*, and others.

The succession of the several phenomena contained in this list is arranged according to the month and day (beginning with the commencement of the year), without regard to the particular years in which they were observed, as in my opinion this method of tabulation will allow a ready and convenient means of reference.

I have not availed myself of the very numerous and valuable notices and researches in the reports of the Luminous Meteor Committee of the British Association for the Advancement of Science (1848 to 1880), as one may hope that a summary of them will be prepared by Professor Herschel.

It is also to be hoped that a general catalogue of the real paths of fireballs will soon be compiled, and that this will include the results of other workers in this field ; for example, Galle, Weiss, Newton, Koerber, &c.

Brünn, Austria :
    1896 *November* 12.